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Aggregate Resources Inventory Paper 2

AGGREGATE RESOURCES INVENTORY OF ADJALA TOWNSHIP SIMCOE COUNTY SOUTHERN ONTARIO

by

Staff of the Engineering and Terrain Geology Section

Ontario Geological Survey

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ABSTRACT

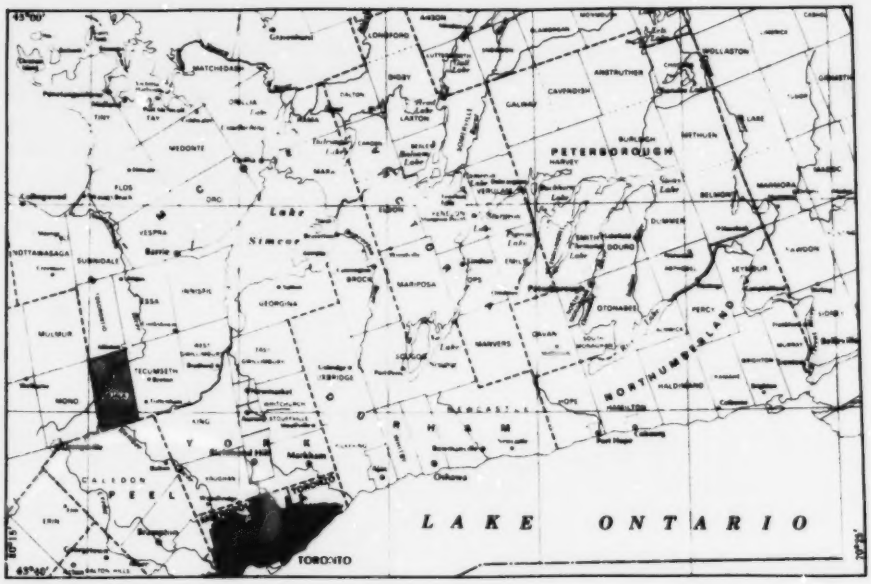


Figure 1 - Key Map Showing Location of Adjala Township, Scale 1: 1, 800,000.

An inventory and evaluation of aggregate resources, including crushed stone derived from bedrock as well as natural sand and gravel, was completed for Adjala Township in 1979, as part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971. The aggregate resources in the township have been assessed according to standards developed for the Program.

In Adjala Township, five areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas comprise 3242 acres (1312 ha), and an estimated 162 million tons (147 million tonnes) are thought to be available for extraction under present conditions. The Selected Areas comprise 13 percent of the total area occupied by sand and gravel deposits in the township and 8 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1, near Gulley Hill, constitutes the most important natural aggregate deposit in the township. This is an ice-contact stratified drift deposit that contains available resources of 25 million tons (23 million tonnes) of sand with minor crushable gravel suitable for a limited range of road-building and construction products.

Selected Resource Areas 2,3,4 and 5 occupy portions of a series of outwash terraces on the south side of the Nottawasaga River. These Areas cover 2755 acres (1115 ha) and contain an estimated 137 million tons (124 million tonnes) of sand with minor gravel suitable for road-base and sub-base aggregate. Quality and quantity data are scarce for these Resource Areas and further investigation is required.

Generally, Adjala Township has low to moderate possible resources of sand and gravel. These resources may not be sufficient for local needs in the near future. Care should be taken to ensure the availability of as much of the remaining resources as possible.

Possible resources derived from bedrock formations in Adjala Township are of only one type. Shale from the Queenston Formation is suitable for brick and tile manufacture and is an important regional resource. The Queenston Formation is not suitable for crushed products used for road building or construction.

Three areas have been selected for resource protection. The Selected Areas cover 1242 acres (503 ha) and contain possible resources of 221 million tons (200 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF ADJALA TOWNSHIP

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1976, the total tonnage of mineral aggregates extracted was greater than that of any other metallic or non-metallic commodity mined in the Province (Ontario Ministry of Natural Resources 1977).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, non-renewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is often greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

Interested groups and individuals are invited to discuss any aspect of this report with staff geologists of the Ontario Geological Survey and with staff of the appropriate Regional and District Offices of the Ontario Ministry of Natural Resources.

PART I – INVENTORY METHODS

Field and Office Methods

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications.Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50,000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50,000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

Resource Tonnage Calculation Techniques

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known, or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor) which is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Col. 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those portions of the deposit lying outside licenced areas (Col.2). Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements and Column 4 accounts for those areas that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Col.5). The available area is then multiplied by the estimated deposit thickness and the density factor (Col. 5 x Col. 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are also calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures.

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed "possible resources" in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975,p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

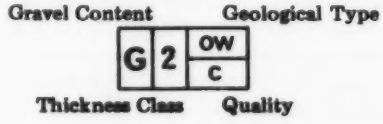
PART II – DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

Map I Distribution of Sand and Gravel Deposits

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel. If no information is available, the letters are omitted.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and particle size distribution. A number of unlicenced pits are

also identified and numbered on Map 1 and described in Table 2.

Map 2 Selected Sand and Gravel Resource Areas

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report but are indicated by a light-grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel for local use and in many cases may provide sites for temporary wayside pits operated by or for the Ontario Ministry of Transportation and Communications and local authorities. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the township's aggregate supply.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles comprising the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithololgy (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites since this content is the mini-

mum from which crushed products can be economically produced.

Excess "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

"Lithology" is the other indicator of the quality of an aggregate. Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality or township should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

Map 3 Bedrock Resources

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, from water well data from the Ontario Ministry of the Environment, from oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical well data, from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These constitute resource areas which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three

factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 4.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN ADJALA TOWNSHIP

Location and Population

Adjala Township occupies an approximately rectangular area of 46,099 acres (18 656 ha) in the southwest corner of Simcoe County. It is shown on portions of the Alliston and Bolton map sheets of the National Topographic System at a scale of 1:50 000.

There are no major population centres in the township. The major trade and retail centre is the Town of Alliston, near the northeast corner of the area.

Total population of Adjala Township in 1976 was 3317. This represents an increase of 20 percent over the last five years (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974, 1977). The majority of the population are rural-farm residents, although recent years have seen a considerable increase in the number of rural-nonfarm residents. Such growth may continue in the near future. As a result, demand for aggregates for use in road and residental construction will also increase.

Road access in the township is good. The area is served by a rectangular grid of paved and gravel-surfaced township concession roads. The township is bounded on the north and south by King's Highways 89 and 9 and is transected by paved Country Roads.

Physiography and Surficial Geology

Adjala Township can be divided into four major physiographic units. The southern third of the area is occupied by rolling sandy hills of ice-contact stratified drift. The central and west-central portions of the township are dominated by the Nottawasaga River, its large valley, and its associated outwash terraces. The northern quarter of the township is topographically irregular and is dominantly bedrock with a thin veneer of till. There are several low, flat areas of lacustrine sediments in the northeastern quadrant of the township.

The physiography and distribution of unconsolidated sediments in the township are largely the result of glacial activity during the latter part of the Pleistocene Epoch, approximately 7 to 85 thousand years ago. Postglacial erosion has significantly modified the physiography of some areas.

During the glacial period the township was covered by large ice masses which advanced from several directions, and on several occasions. Each advance, and subsequent melting and retreat of the ice margin, left characteristic deposits and landforms.

There are several different till deposits in the township, each of which represents deposition during a glacial advance (Gwyn 1972, 1975; and Cowan 1976). The Newmarket Till is the dominant till unit in Adjala Township. This till was deposited by an ice lobe moving southwestward out of the Lake Simcoe basin. It is a sandy silt till and is found in the northern and east-central portions of the township. It has no economic value as an aggregate source. After deposition of the Newmarket Till, the ice margin retreated from the area. Meltwaters became ponded in various areas, leading to the deposition of glaciolacustrine silt and clay, in the northern part of the township.

The last ice advanced from the south and deposited the Halton Till (not found in Adjala Township). Meltwaters from the melting "Halton" ice deposited, in the southern third of the township, extensive ice-contact stratified drift consisting of poorly to well sorted sand with minor gravel (White 1975). Pockets of coarse gravel suitable for crushing are found near Gulley Hill. These pockets represent one of the few areas of crushable aggregate available in Adjala Township.

The last glacial event in the Lake Simcoe basin resulted in sediment-laden meltwaters which deposited large amounts of sand and gravel in an extensive outwash apron stretching west from the ice margin to the base of the Niagara Escarpment (Gwyn 1975). These sediments were transported and reworked by postglacial runoff along the Nottawasaga River valley, and were redeposited in several low

alluvial terraces east of Hockley. The terraces consist mainly of sand and silty sand but may contain thin lenses of coarse material.

In the northern portion of the township the bedrock surface controls the physiography. Rocks of the Georgian Bay Formation are thinly covered by till. The land surface is a rolling till plain with long, fairly simple slopes, and occasional drumlinoid ridges of moulded till. Soils developed on the till generally have a silt to clay loam texture, and are well suited for a variety of close grown crops and pasturage. Virtually all the land surface in this region has been cleared for agriculture (Hoffman et al. 1962, p.84).

A broad undulating plain forming the north-central portion of the township is referred to as the Essa Flats of the Simcoe Lowlands Physiographic Region (Chapman and Putnam 1966, p.299). It adjoins a similar plain in the Nottawasaga River valley. Soils developed on the fine sand and silt of these plains generally have a heavy texture and are poorly drained. Less than half of the land in the Essa Flats is cleared for agriculture.

The west-central portion of the township is dominated by an extensive, pitted outwash plain at approximately 975 feet (297 m) above sea level (a.s.l.). The plain is now dissected by numerous gullies and stream valleys. In much of the area, topography inhibits farming and the soil is extremely susceptible to erosion. Elsewhere droughtiness and low fertility make the soils poor to fair for most crops. Reforestation, especially on steep slopes, is common.

The northwestern part of the township is thinly drift covered. Shales of the Queenston Formation are near the surface and underlie ice-contact stratified sand with minor gravel. Soils developed on these deposits are considered to be poor to fair for agricultural purposes, and the main agricultural land use is natural and improved pasturage.

Extractive Activity

Although granular materials are common in the township, gravel-sized aggregate is scarce, making up less than 15 percent of the total aggregate resources (see Table 1). More than a dozen sand and gravel pits have been opened; most are small sites where material was extracted for local use. Since designation of the township under terms of The Pits and Quarries Control Act, 1971, many existing pits have been abandoned. At the time of writing, three pits were licenced under the Act. Their names and locations are given in Table 2. The total area licenced for extraction is 525.5 acres (212.7 ha). After accounting for those portions of the licenced areas which have been previously extracted and the areas which will not be extracted (according to site plans filed with the Ontario Ministry of Natural Resources), total available sand and gravel resources contained within the licenced areas are estimated to be 29 million tons (26 million tonnes).

Total production from licenced sources is compiled annually by the Mineral Resources Branch of the Ontario Ministry of Natural Resources. The average annual production from licenced properties and wayside pits over the last 5 years in Adjala Township has been approximately 0.4 million tons (0.3 million tonnes).

Selected Sand and Gravel Resources

Sand and gravel underlies 24,523 acres (9924 ha) or approximately 60 percent of the total area of Adjala Township. Much of the material included in this estimate, especially the ice-contact stratified drift, has low potential for use. As indicated in Table 1, resources in deposits which consist of gravel are 145 million tons (132 million tonnes) or approximately 7 percent of the total estimated granular material in the township. Economically viable deposits cover 2994 acres (1212 ha) or 12 percent of the township's area.

Five deposits have been selected as areas of primary significance for possible resource protection; they are listed in Table 3. Four of the Areas contain predominantly crushable aggregate and have total possible resources of 88 million tons (80 million tonnes) covering 2094 acres (847 ha).

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is part of a large area of ice-contact stratified drift. It has been distinguished from the rest of the deposit on the basis of its topography, on water

well and pit data. These indicate a significant textural difference between Area 1 and the surrounding material which consists predominantly of stratified sand and silt. The topography is rolling, dissected by erosion, and local relief is in excess of 200 feet (61 m).

There are two licenced pits covering nearly 50 acres (20 ha) at the east end of the deposit. The western end of the deposit shows several abandoned pits. Faces in these pits range in height from 20 to 40 feet (6 to 12 m) and expose poorly to moderately sorted and stratified gravel with stone contents ranging from 40 to 60 percent. Indications are that the gravel is overlain by 5 to 30 feet (2 to 9 m) of well stratified sand.

Assuming an average thickness of 25 feet (8 m), it is estimated that resources of 25 million tons (23 million tonnes) are presently available for extraction in Area 1.

Data for the deposit, from the Ontario Ministry of Transportation and Communications, indicate that stone quality is too poor (because of high siltstone content) to be used for asphaltic mixes. Road sub-base products such as Granular Base Course (G.B.C.) "A, B and C" can be produced (Deike 1977). Gwyn (1976) notes that extensive cementation of the gravel in the western part of the deposit may hinder extraction. This is probably the reason for the scattered nature of extraction in the area.

Resource Area 1 is entirely within the Niagara Escarpment Planning Area and may be subject to constraints. Telford and Narain (1976) have identified most of the Area as a high priority resource area for crushable material. It is important to the resource base of the township that this deposit be protected.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is the portion of the lowest outwash terrace on the south side of the Nottawasaga River valley, which extends from Hockley to the Second Concession Road. The Area has an available acreage of 461 acres (187 ha) and, assuming an average thickness of 15 feet (5 m), has possible resources of 17 million tons (15 million tonnes), presently available for extraction.

Although no pits have been opened in the deposit (either in Adjala Township or in adjoining Mono Township), water well data, geology, topography and surface exposures indicate that it consists of fairly uniform, moderately sorted sand and sandy gravel. No quality data are available.

The land surface in the Area is level, smooth and mainly bush covered. The Area is above the Nottawasaga River floodplain so is not affected by high water levels. Some material will not be available near Hockley at the west end of the deposit. Resource Area 2 has great potential as a source of aggregate but additional data will be required to evaluate the deposit fully.

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Resource Area 3 is also on the lowest outwash terrace, but to the east of Area 2. The river valley widens considerably in the vicinity of Area 3 and the terrace is broad and indistinct. The outwash is overlain in places by a veneer of windblown fine sand.

Again, there are no pits developed in this portion of the deposit so that thickness estimates and tonnage calculations are based on topography, geology and water well data. Area 3 has an available acreage of 399 acres (161 ha) and assuming an average thickness of 15 feet (5 m), has possible sand and gravel resources of 15 million tons (14 million tonnes), available for extraction.

Much of the deposit is covered by bush and wood lots. A high water table may limit extraction in some areas. Area 3 has been identified on the basis of limited data. Further investigation will be required to fully evaluate the deposit.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Sand and Gravel Resource Area 4 is adjacent to Area 3 and is a portion of an indistinct, intermediate level outwash terrace at approximately 850 feet (259 m) a.s.l. There is little information on the thickness and texture of the aggregate in the deposit. Pit number 5 (Map 1), now abandoned, was opened in the northern end of Area 4 and a 20-foot (6 m) face in the pit exposes stratified sand and gravel with

a 20 to 40 percent stone content. Assuming an average deposit thickness of 15 feet (5 m),available sand and gravel resources are estimated to be 31 million tons (28 million tonnes). The land surface is smooth to rolling and is cleared for cultivation.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Selected Sand and Gravel Resource Area 5 comprises the southern portion of the large, pitted outwash plain which covers much of west-central Adjala Township. The uppermost portion of Area 5 consists of silty sand with occasional layers of sandy gravel. The upper unit is 6 to 35 feet (2 to 11 m) thick and overlies interbedded sand and gravel, lacustrine silt and till (Gwyn 1975, p.82).

No pits are developed in this deposit but water well data in Adjala Township and in Mono Township indicate that an average of 45 feet (14 m) of sandy gravel is present. The deposit has an available acreage of 657 acres (266 ha) and possible resources of 74 million tons (67 million tonnes).

No quality data are available but it is probable that the material is suitable for low specification uses such as G.B.C. "B" and "C", sand cushion and fill. The fine fraction may be suitable for some uses but variable silt and clay content is a limiting factor.

The upland surface is relatively smooth but is extensively dissected on terrace scarps, which may limit extraction. The land has been cleared but the soils are droughty and susceptible to erosion. An air field is located in the middle of the terrace and, it too, may limit extraction. As with Resource Area 2, directly adjacent to the north, Area 5 is within the Niagara Escarpment Planning Area and so may be subject to planning constraints. Telford and Narain (1976) identified this area as a high priority sand resource.

SAND AND GRAVEL RESOURCES OF SECONDARY SIGNIFICANCE

A portion of the pitted outwash plain at the western boundary of the township has been selected as a Sand and Gravel Resource Area of Secondary Significance. The plain has a flat surface at approximately 975 feet (297 m) a.s.l. and is dissected on its edges by tributaries of the Nottawasaga River. Gwyn and White (1973) note that "The material is predominantly medium-grained to fine-grained sand with small amounts of pebbly sand. Gravel is rarely found at the surface, usually occurring under a blanket of silty sand." Water well data in the Area indicate that considerable thicknesses of sandy aggregate may be present. Only one pit has been developed in the deposit and aggregate suitability data are lacking. Generally, crushing potential is low in the Resource Area and further detailed investigation would be required to identify areas suitable for extractive development.

Bedrock Geology

Adjala Township is underlain by Ordovician shales of the Whitby, Georgian Bay and Queenston Formations (Telford, Bond and Liberty 1975a, b, c). The units are exposed in northwest-southeast trending bands and have a gentle regional dip to the southwest. Overburden is thick and surface exposures are found only in the northwest and southwest corners of the township.

Brown shale of the Whitby Formation occurs in the northeast portion of the township (Hewitt 1972, p.7). There are no surface exposures of this unit and drift cover is consistently too great to permit quarrying (Gwyn and Fraser 1975a, b).

Most of the township is underlain by the blue and grey shales of the Georgian Bay Formation. These shales have been extracted near Toronto and Cooksville for brick manufacture, and some heat-expanded aggregate has been produced at Cooksville. Drift cover overlying the Georgian Bay Formation is too great throughout most of the township, but quarrying may be feasible in the north just east of Hockley.

Red and green shales of the Queenston Formation are found in subcrop in two areas along the western boundary of the township: a small area near Rosemount, and a relatively large area in the southwest corner of the township. In both areas, drift cover is thin enough to permit quarrying and the areas have large possible resources. The Queenston Formation is an important source of raw material for the brick and tile manufacturing industry and has been extensively quarried for that purpose elsewhere in the Province.

Selected Bedrock Resources

Adjala Township has no bedrock resources suitable for road-building or construction uses. Of the three bedrock formations which occur in the township, none has suitable performance characteristics for such uses. Only the Queenston Formation has significant economic value. Three Resource Areas have been identified (see Table 6) as possible sources of shale for brick and tile manufacture.

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 lies in the northwest corner of Adjala Township, south of Rosemount. Portions of the Area extend into Mono Township and Mulmur Township where the deposit has also been selected for possible resource protection. Area 1 has an available acreage of 640 acres (259 ha) and, assuming a workable thickness of 60 feet (18 m), has available resources of 123 million tons (112 million tonnes).

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 lies just to the north of Area 3, along the western boundary of the township. Although there are no surface exposures, drift thickness is less than 25 feet (8 m). The area has an available acreage of 419 acres (170 ha) and has possible resources of 80 million tons (73 million tonnes) presently available for extraction. Although most of the land surface in the Area is smooth and rolling, the valley of the Humber River and a small tributary cut through the centre of the Area, and the wooded valley may limit the extent of possible extraction.

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 covers 113 acres (46 ha) in the extreme southwest corner of the township. Two small areas are surface exposures which cover 18 acres (7 ha). A further 95 acres (38 ha) have a drift cover of less than 25 feet (8 m).

Available resources in Resource Area 3 are estimated to be 18 million tons (16 million tonnes). Although the Queenston Formation may be more than 300 feet (91 m) thick in this Area, calculations of reserves have been made on the basis of a workable thickness of 60 feet (18 m).

Summary

Adjala Township has moderate reserves of granular resources. Much of this material is of limited use because it cannot meet aggregate quality standards set by the Ontario Ministry of Transportation and Communications. Five Selected Sand and Gravel Resource Areas have been chosen, containing an estimated 162 million tons (147 million tonnes) of crushable material.

There are no sources of crushed bedrock aggregate suitable for road-building or construction uses in Adjala Township, but the Queenston Formation is of economic value as a source of material for brick and tile products. Total resources of Queenston shale in the township are 502 million tons (455 million tonnes) (Table 4), of which 221 million tons (200 million tonnes) have been selected for possible resource protection.

Enquiries regarding the Aggregate Resources Inventory of Adjala Township should be directed to the Ontario Ministry of Natural Resources either at the Huronia District Office, Midhurst, Ontario, L0L 1X0 (tel.(705) 728-2900) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (tel.(416) 884-9203).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, ADJALA TOWNSHIP

1 CLASS NO.	2 DEPOSIT TYPE (See Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G-OW	207 (84)	28 (25)
	S-OW	5582 (2259)	457 (415)
	G-IC	648 (262)	32 (29)
	S-IC	13,841 (5601)	1384 (1256)
2	G-OW	2017 (816)	82 (74)
	S-OW	1956 (792)	58 (53)
	S-IC	32 (13)	<1 (<1)
3	G-OW	122 (49)	3 (3)
	S-OW	88 (36)	2 (2)
4	S-OW	14 (6)	<1 (<1)
	S-IC	16 (6)	<1 (<1)
		24,523 (9924)	2046 (1856)

TABLE 2 | SAND AND GRAVEL PITS, ADJALA TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1.	A494	Town of Caledon	Pt. 9	2	97.5 (39.5)	25 (8)	60
2.	A4-95	James Dick Construction Ltd.	W½ 8,9, 10	3	392.0 (158.6)	20 (6)	
	A4-19		E½, 10	2			
3.	B10-113	Armstrong Holdings	Pt. 1	5	36.0 (14.6)	12 (4)	35-70
					525.5 (212.7)		
UNLICENCED PITS							
4.	A4-65	Illes	17	1			
5.	A4-4	McKenna	20	5		20 (6)	

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, ADJALA TOWNSHIP

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	487 (197)	35 (14)	48 (19)	404 (163)	25 (8)	25 (23)
2	590 (239)	129 (52)	0 (0)	461 (187)	15 (5)	17 (15)
3	449 (182)	50 (20)	0 (0)	399 (161)	15 (5)	15 (14)
4	978 (396)	148 (60)	0 (0)	830 (336)	15 (5)	31 (28)
5	738 (299)	81 (33)	0 (0)	657 (266)	45 (14)	74 (67)
	3242 (1312)	443 (179)	48 (19)	2751 (1113)		162 (147)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, ADJALA TOWNSHIP

1 DRIFT THICKNESS	2 FORMATION	3 WORKABLE THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	6 ORIGINAL TONNAGE Millions of Tons (Tonnes)
0-3 (0-1)	Georgian Bay	-	-	-
3-25 (1-8)	Georgian Bay	60 (18)	2032 (822)	390 (354)
25-50 (8-15)	Georgian Bay	60 (18)	2026 (820)	389 (353)
			4058 (1642)	779 (707)
0-3 (0-1)	Queenston	60 (18)	18 (7)	3 (3)
3-25 (1-8)	Queenston	60 (18)	1180 (478)	226 (205)
25-50 (8-15)	Queenston	60 (18)	1421 (575)	273 (248)
			2619 (1060)	502 (455)
			6677 (2702)	1281 (1162)

TABLE 5 QUARRIES, ADJALA TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

NONE

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, ADJALA TOWNSHIP

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE TONNAGE Millions of Tons (Tonnes)
1.	0-25 (0-8)	674 (273)	34 (14)	0	640 (259)	60 (18)	123 (112)
2.	0-25 (0-8)	455 (184)	36 (15)	0	419 (170)	60 (18)	80 (73)
3.	0-25 (0-8)	113 (46)	17 (7)	0	96 (39)	60 (18)	18 (16)
		1242 (503)	87 (35)	0 (0)	1155 (467)		221 (200)

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APPENDIX B-GLOSSARY

ABRASION RESISTANCE: Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN: A period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT: See fines.

DOLOSTONE: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT: A special term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (.074 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GLACIAL LOBE: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		> 256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, Clay		<074 mm

GRANULAR BASE COURSE: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE): Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1,3 and 4), or as binder course (H.L. 2,6 and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

PLEISTOCENE: An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE: Reserves estimates based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURIAN: An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN: Pertaining to the last glacial period of the Pleistocene Epoch in North America. It began approximately 85,000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C-GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7 to 85 thousand years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

Kames (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated" ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames often contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the occasional presence of excess fines (silt and clay-sized particles).

Eskers (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many municipalities.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits often extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC)

This designation may include deposits from several ice-contact, depositional environments which often form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL)

Alluvium is a general term for clay, silt, sand, gravel or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, but it has generally low value due to the presence of excess silt and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material often predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the deposit is developed from coarse-grained deposits such as a stoney till, and low when developed on fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be quite large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plain (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which comprise the plain are predominantly fine to medium sand, silt and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They frequently consist of ice-contact stratified drift and in such instances are often called kame moraines. Kame moraines frequently result from deposition between two glacial lobes (inter-lobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Forms (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

Figure 2 - Bedrock Geology of Southern Ontario.

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium-to massive-bedded, aphanitic, brown dolostone with shaley partings. Thickness: 35 to 60 feet (10-18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunville. Los Angeles Abrasion Test: 17-35%; Absorption: 1.4%. Shaley portions are unsuitable for aggregate due to high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium to thin-bedded, fine-grained limestone with some argillaceous and shaley partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium-to thin-bedded, cherty limestone, often fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine – to medium – crystalline, brownish grey, medium-to thick-bedded, dolomitic limestone with shaley partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32%; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin-to thick-bedded, interbedded grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestone with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Georgetown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Georgetown to Niagara Falls): thin-to massive-bedded, fine - to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine-to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarance Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine-to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with occasional to numerous shaley partings, 450-475 feet (137-145 m) thick near Ottawa. Uses: The Leray, Rockland and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium - to thick-bedded, grey dolostone, with some shaley partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES.

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium-to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces

80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized white limestone and dolostone, fine-to coarse-grained, often of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic-to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

Lindsay Formation (Middle Ordovician)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaley partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and often weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities and frequent clayey interbeds, low abrasion resistance, high soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with occasional limey or sandy lenses. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville (Guillet 1967) produce brick and structural tile. Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group comprises six formations. Only the Arkona is of commercial value. It is a soft, light grey, calareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region (Guillet 1967) and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

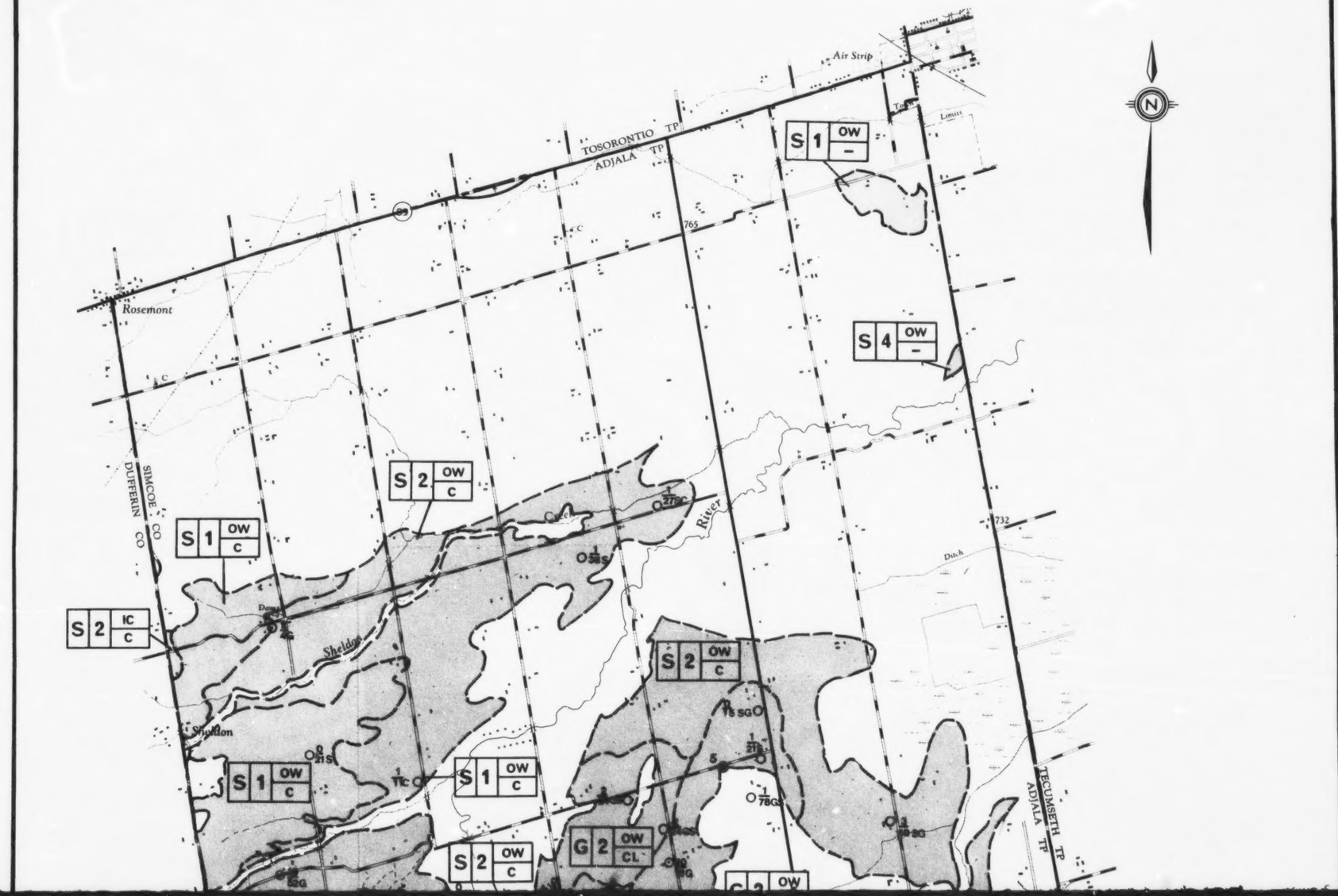
Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite and gypsum. The formation consists predominantly of eva-

porite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburgh, Windsor and Sarnia.

Whitby Formation (Upper Ordovician)

(Formerly known as Collingwood shale near Toronto). Composition: Brown, black, fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.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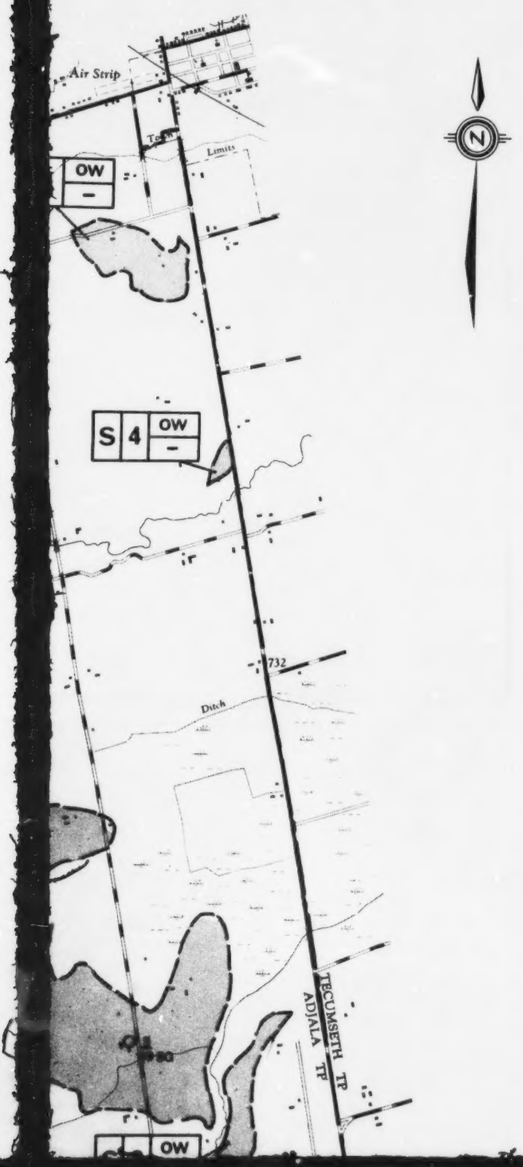

Ministry of Natural Resources

Hon. James A.C. Auld
Minister

Dr. J.K. Reynolds
Deputy Minister

Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ADJALA TOWNSHIP

SIMCOE COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale: 1:50,000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference. 31 D/4W, 31 M/13W

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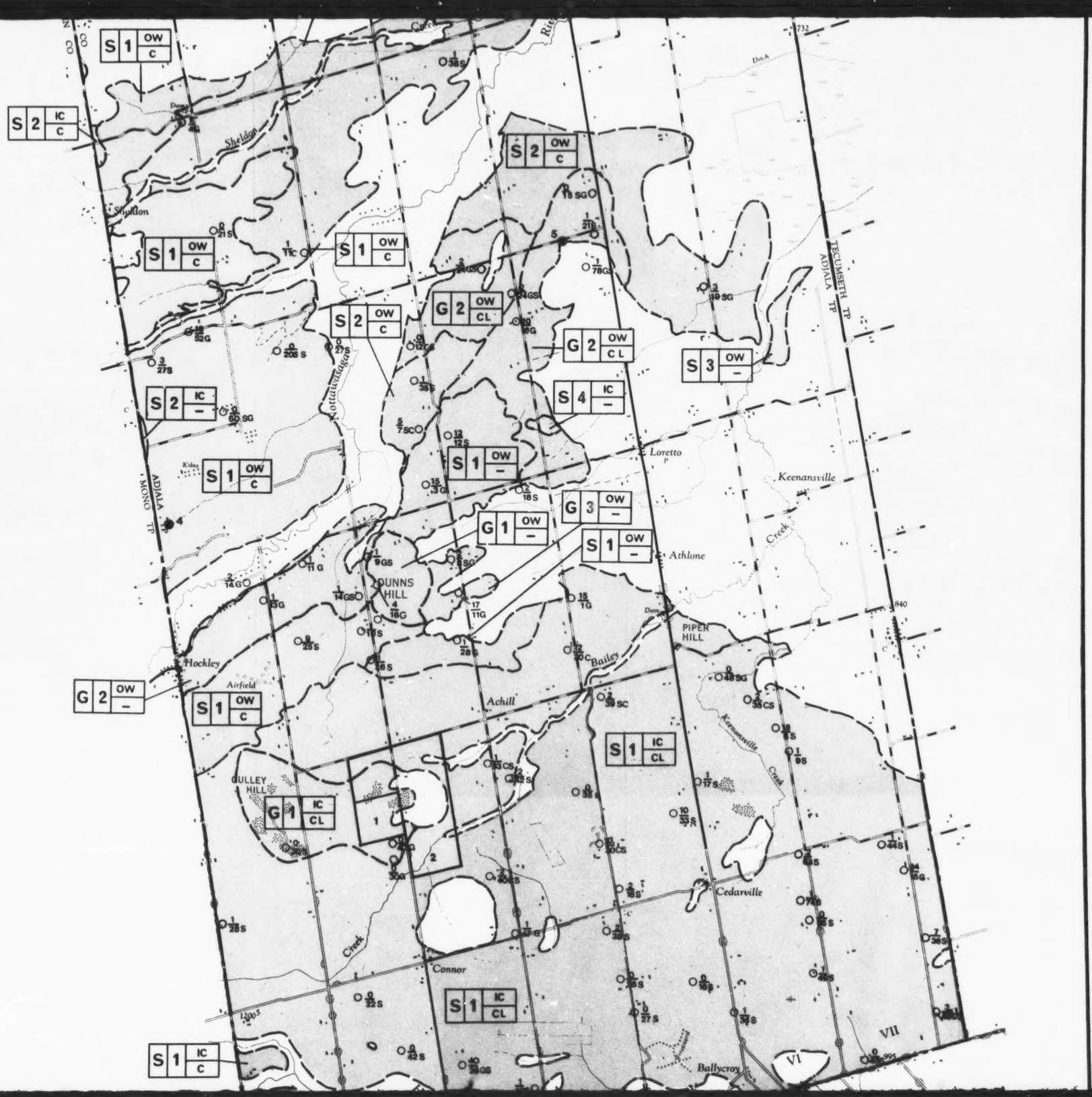
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SYMBOLS

Geological and aggregate thickness boundary. Shading indicates deposit area.

S1 IC CLO — Deposit symbol: see below.

3 — Licenced property boundary; Property number: see Table 2.

4 — Unlicenced sand or gravel pit; Property number: See Table 2.

6/23 — Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet). (Note: S-sand, G-gravel, C-clay, T-till)

DEPOSIT SYMBOL

Deposits are identified by gravel content, thickness class, deposit type and quality indicators. Gravel content is expressed as percentage of crushable material. Classes are based on potential aggregate tonnage per acre and are designated numerically. Type refers to geologic origin. Quality modifiers indicate variations in grain size distribution and lithology.

Gravel Content	Thickness Class	Geological Type
		Quality Indicators

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.
?	Requires investigation

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 18 500)
2	10-20 (3-6)	25,000-50,000 (9 000-18 500)
3	5-10 (1.5-3)	12,500-25,000 (4 500-9 000)
4	less than 5 (< 1.5)	less than 12,500 (< 4 500)

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
		LB	Lacustrine Beach
ICT	Ice-Contact Terrace	LP	Lacustrine Plain
K	Kame	LD	Lacustrine Delta
E	Esker	AL	Older Alluvium
EM	End Moraine	WD	Windblown Forms

(see Appendix C for descriptions of Geological Types.)

Quality Indicators

	If blank, no known limitations present
C	Clay and/or silt (fines) present in objectionable quantities
L	Deleterious lithologies present
O	Oversize particles or fragments present in objectionable quantities
–	Requires investigation

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
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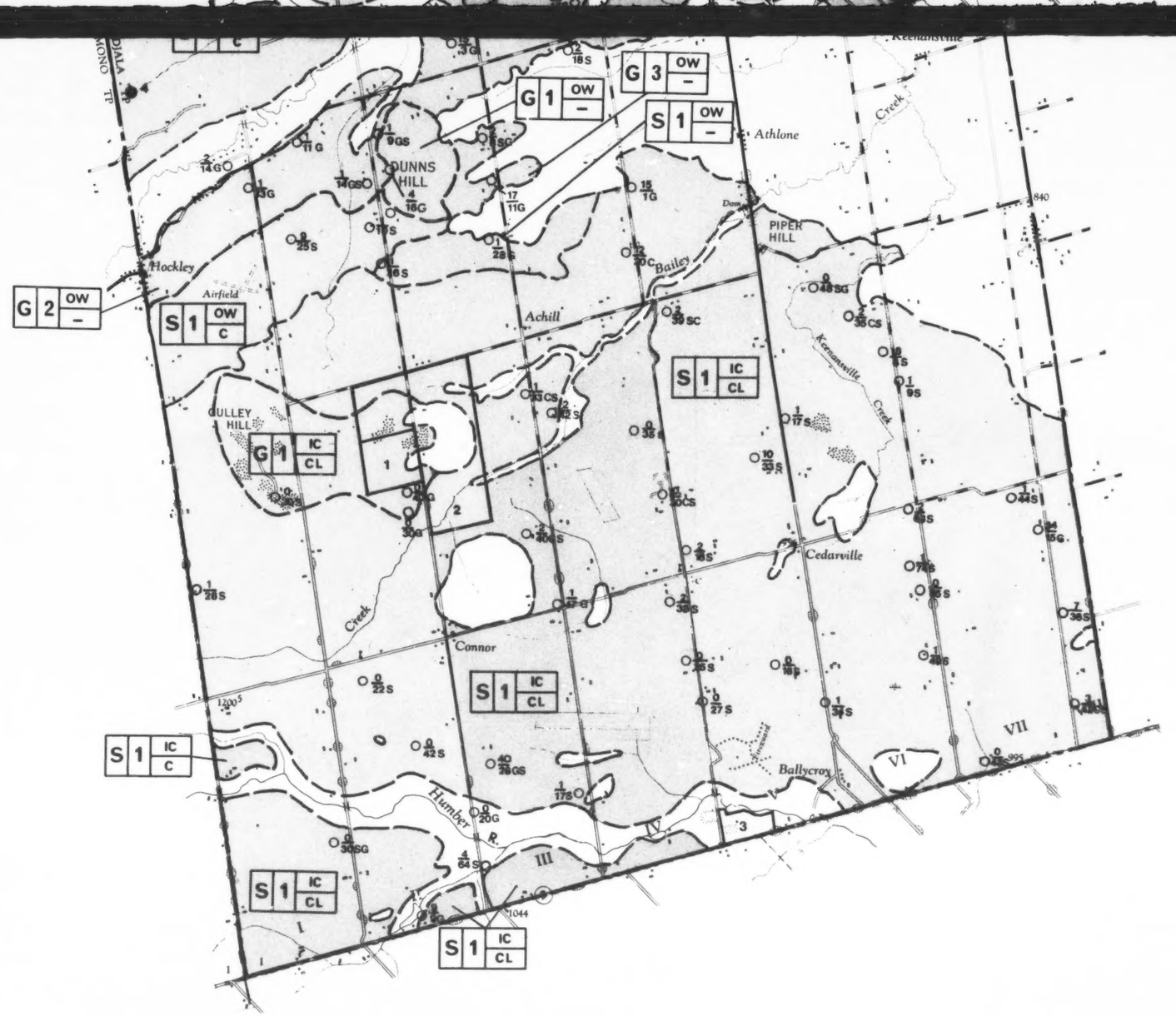
Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural



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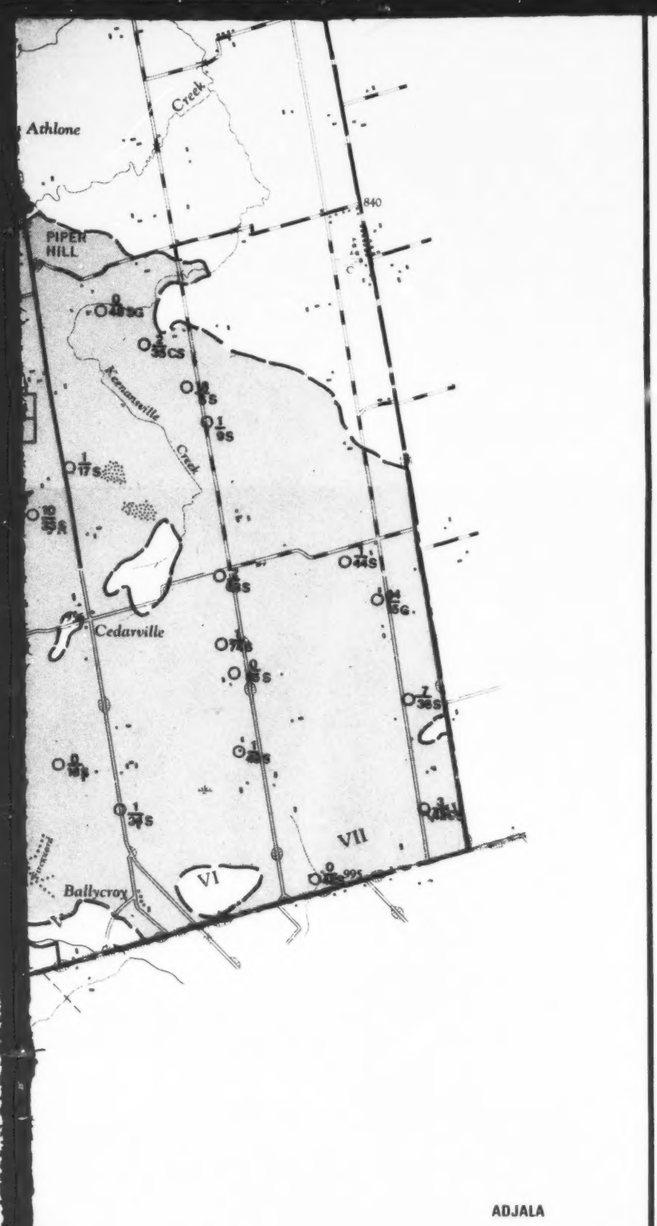

ADJALA

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Geology by W.R. Cowan 1976
O.H.J. Gwyn 1972
O.H.J. Gwyn 1975
O.H.J. Gwyn and J.Z. Fraser, 1975
O.H.J. Gwyn and S. White 1973
P.G. Telford, I.J. Bond and B.A. Liberty, 1976.
O.L. White, 1975.

Compilation and drafting by C.M. Kwiatkowski

Issued 1980

This map is published with the permission of E.G. Pye, Director, Ontario Geological Survey.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 2.

Ministry of Natural Resources

Ontario

ONTARIO GEOLOG
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MAP 2
SELECTED SAND
RESOURCE

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Ministry of Natural Resources

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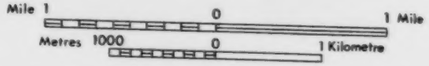
ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ADJALA TOWNSHIP

SIMCOE COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale: 1:50,000



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Ontario Ministry of Natural Resources

ONTARIO GEOLOGI
AGGREGATE RESOURC

ADJALA TO
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MAP 2
SELECTED SAND
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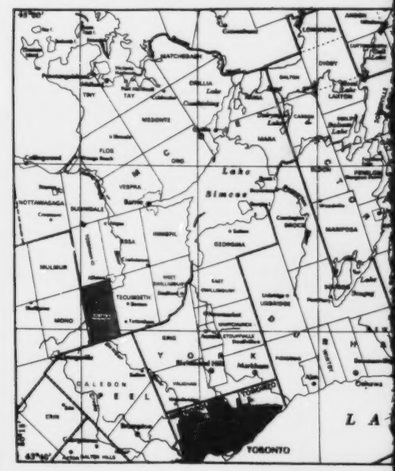

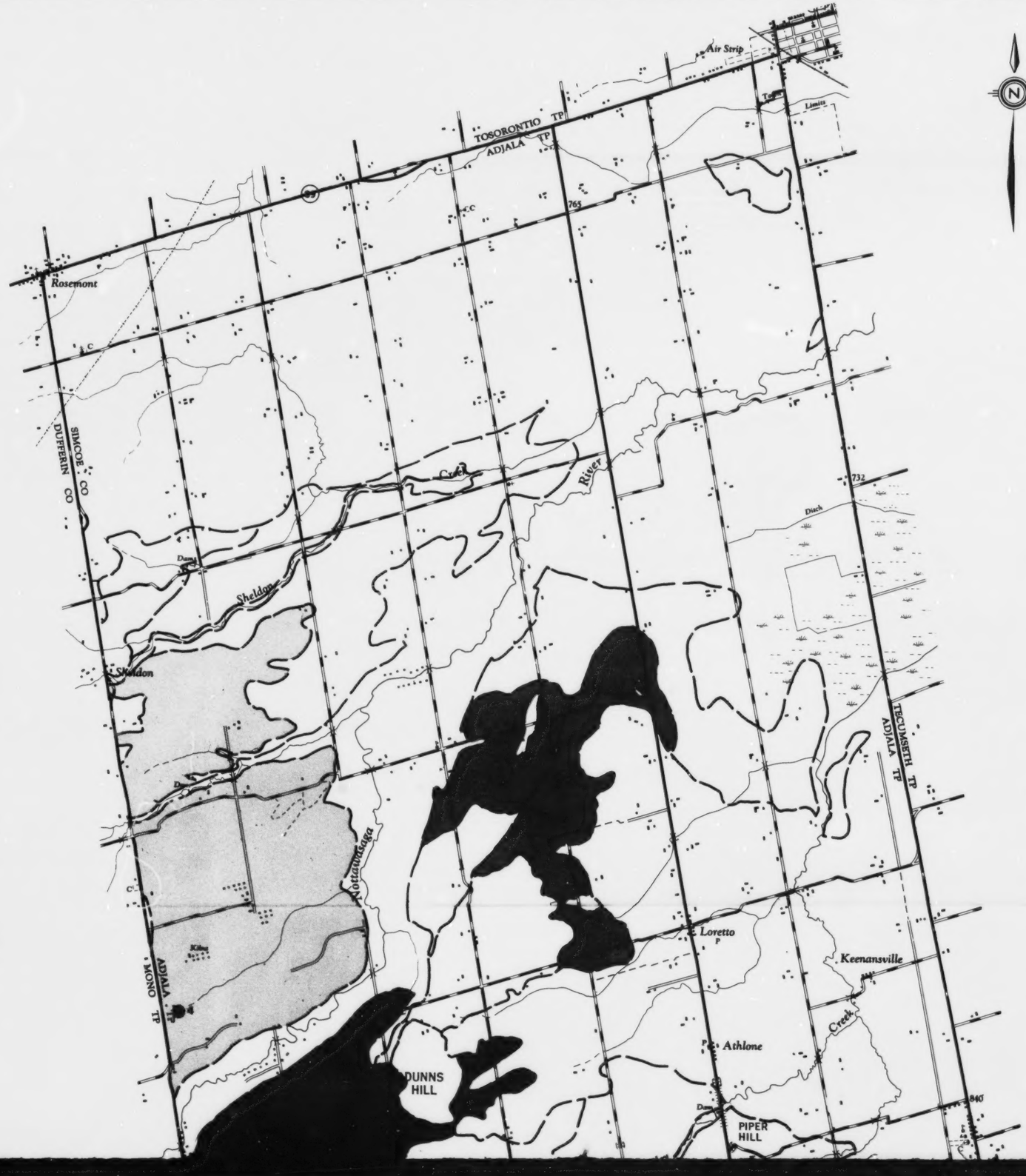

SYMBOLS

- Geological and aggregate thickn
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  Deposit number: see Table 3.
- Selected sand and gravel resou
- Selected sand and gravel resou
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- 4 Unlicenced sand or gravel pit;

SOURCES OF INF

Base map by Surveys and Mapping Br
Natural Resources.
Licence data from District and Regional
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Aggregate suitability data from the Eng
Ontario Ministry of Transportation and Co

Ontario Ministry of Natural Resources

Dr. J.K. Reynolds
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ADJALA TOWNSHIP

SIMCOE COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale: 1:50,000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 31 D/4W, 31 M/13W

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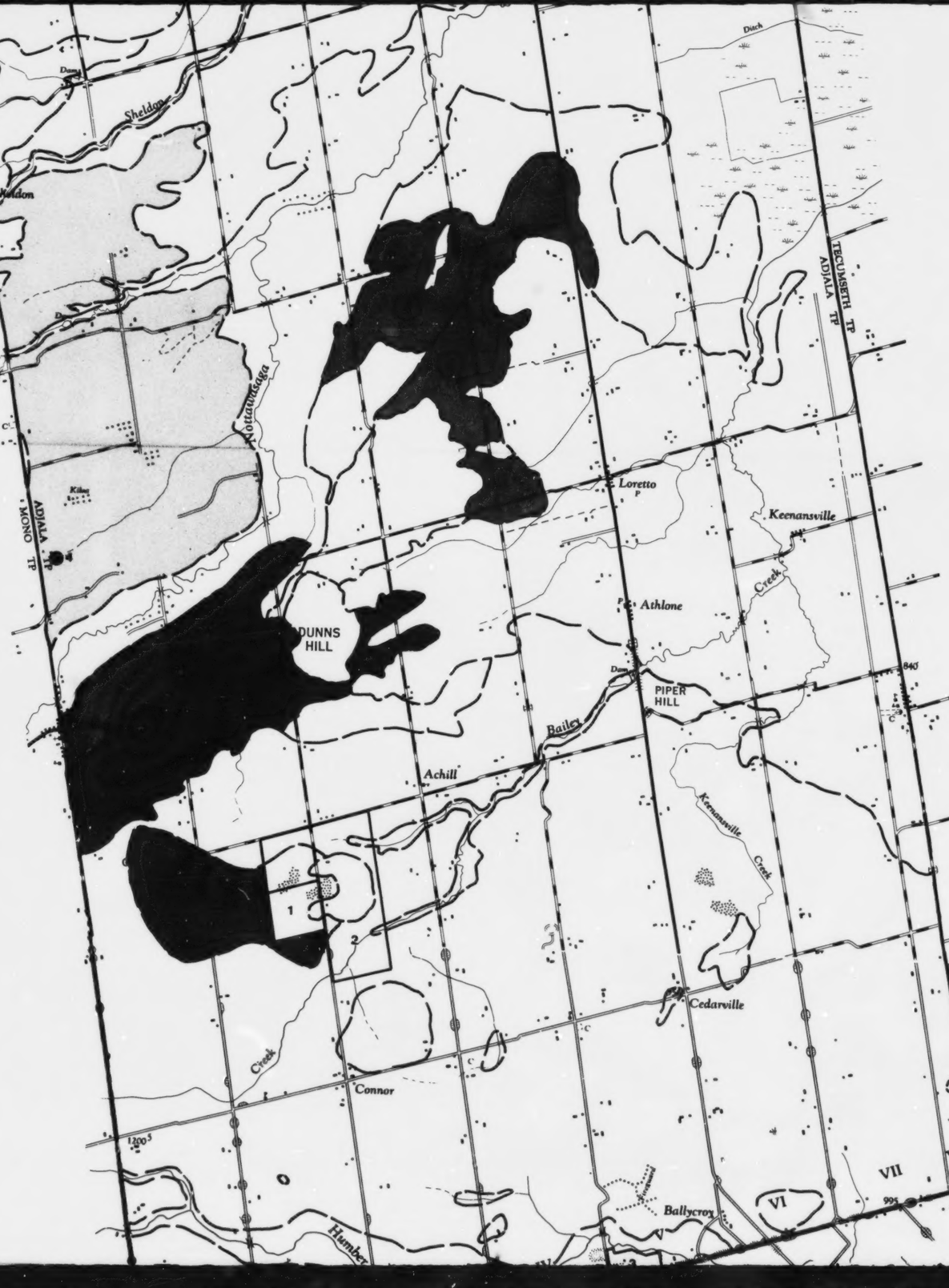
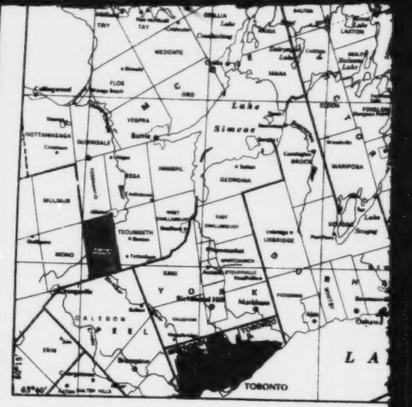
SYMBOLS

- Geological and aggregate thickness boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- Licenced property boundary; Property number: see Table 2.
- Unlicenced sand or gravel pit; Property number: see Table 2.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilling data from the Ontario Ministry of the Environment





SYMBOLS

Geological and aggregate thickne

Selected sand and gravel resou
Deposit number: see Table 3.

Selected sand and gravel resourc

Selected sand and gravel resou

Licenced property boundary; P

Unlicenced sand or gravel pit; P

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Compilation and drafting by C.M. Kwiatkows

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Paper 2 .

SYMBOLS

- Geological and aggregate thickness boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 2 — Licenced property boundary; Property number: see Table 2.
- ●4 — Unlicenced sand or gravel pit; Property number: see Table 2.

SOURCES OF INFORMATION

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Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural Resources.

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P.G. Telford, I.J. Bond and B.A. Liberty, 1975
O.L. White, 1975

Compilation and drafting by C.M. Kwiatkowski

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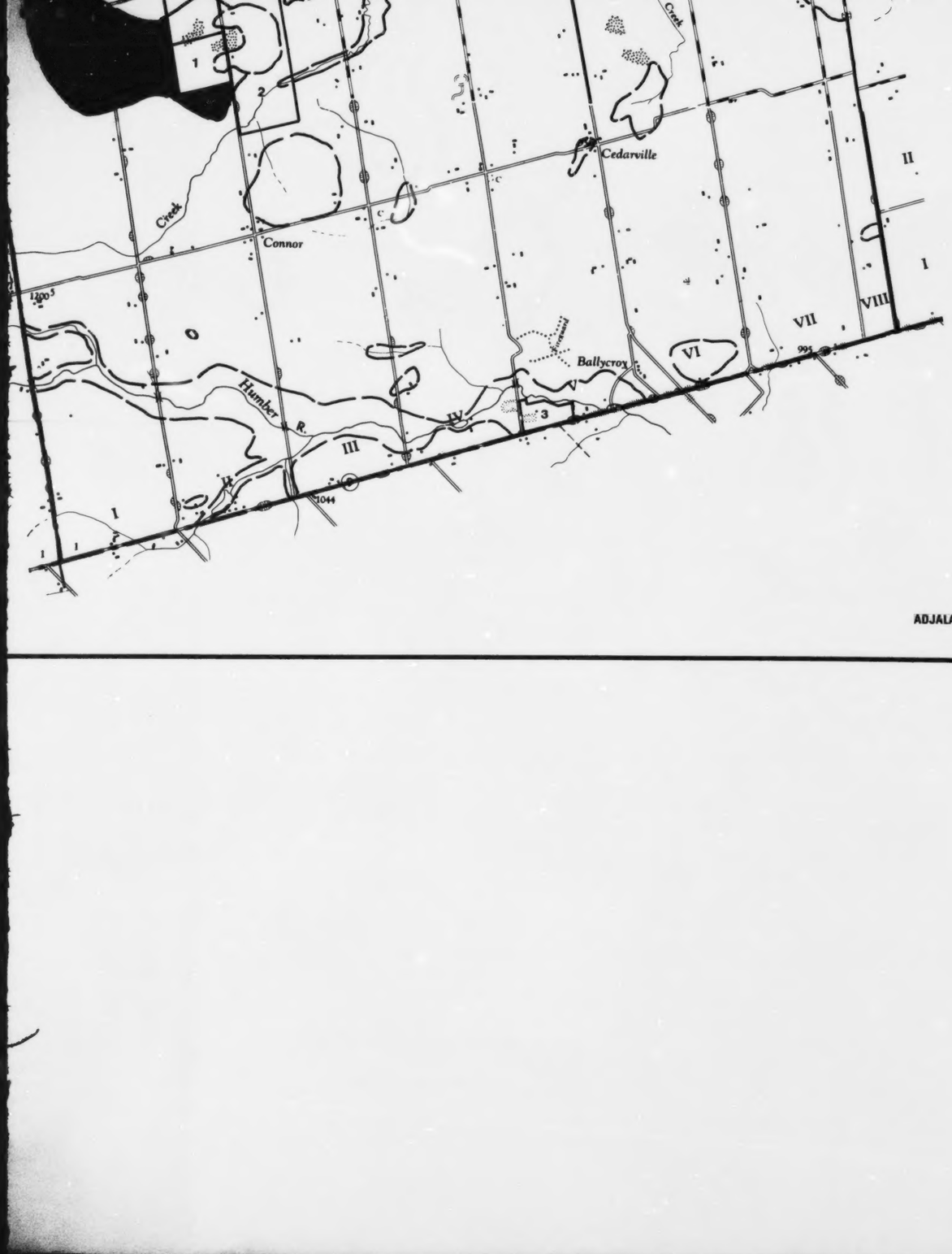

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Q.H.J. Gwyn and S. White, 1973

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Ministry of Natural Resources

Ontario

ONTARIO GEOLOGI
AGGREGATE RESOURCE

ADJALA TOW

SIMCOE CO

MAP 3
BEDROCK RES

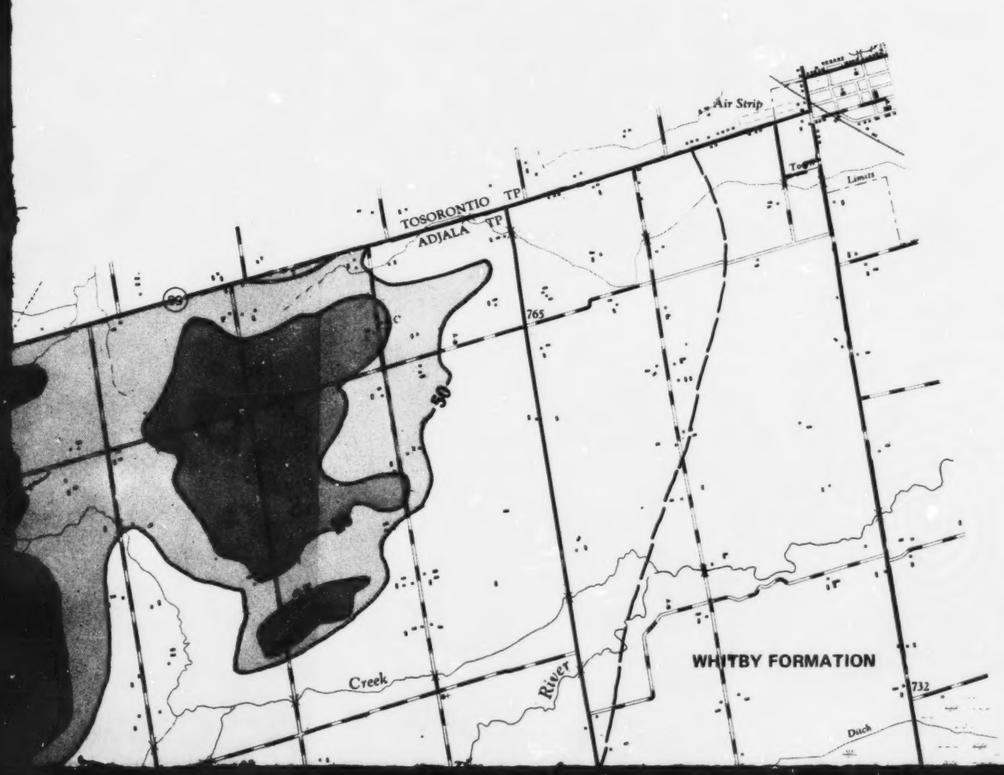
Scale: 1:50,000

Mile 1 0
Metres 1000 0

NTS Reference: 31 D/4

© OMNR-OGS 1980

MAP 3



Ministry of Natural Resources

Ontario

Hon. James A.C. Auld
Minister

Dr. J.K. Reynolds
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ADJALA TOWNSHIP

SIMCOE COUNTY

MAP 3
BEDROCK RESOURCES

Scale: 1:50,000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 31 D/4W, 31 M/13W

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MAP 3

MAP 3
BEDROCK RESO

Scale: 1:50,000

Mile 1 0
Metres 1000 0

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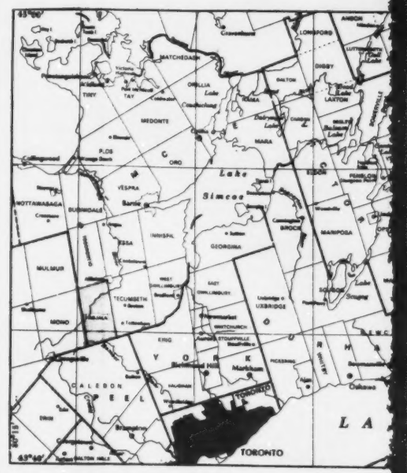

LEGEND

PALEOZOIC
ORDOVICIAN
UPPER ORDOVICIAN
QUEENSTON FORMATI
Red shale
GEORGIAN BAY FORM
Grey shale with lime
stone upper member
WHITBY FORMATION
Grey and black shale

SYMBOLS

Geological boundary.

25 Drift thickness contour line (25 fo

X Isolated bedrock outcrop.

Bedrock within 3 feet (1 m) of sur

Bedrock covered by 3 to 25 feet
see Table 4.

Bedrock covered by 25 to 50 feet
den: see Table 4.

Selected bedrock resource area;

O 27 Selected drilling location indicatin
(in feet).

WHITBY FORMATION

GEORGIAN BAY FORMATION

DUNNS HILL

PIPER HILL

GULLEY HILL

DUFFERIN CO.

ADJALA TP.

MONO TP.

TECUMSETH TP.

Creek

River

Sheldon

Hockley

Airfield

Achill

Bailey

Nottawasaga

Dutch

Athlone

Loretto

Keenansville

Kilns

Dam

765

732

840

MAP 3
BEDROCK RESOURCES

Scale: 1:50,000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

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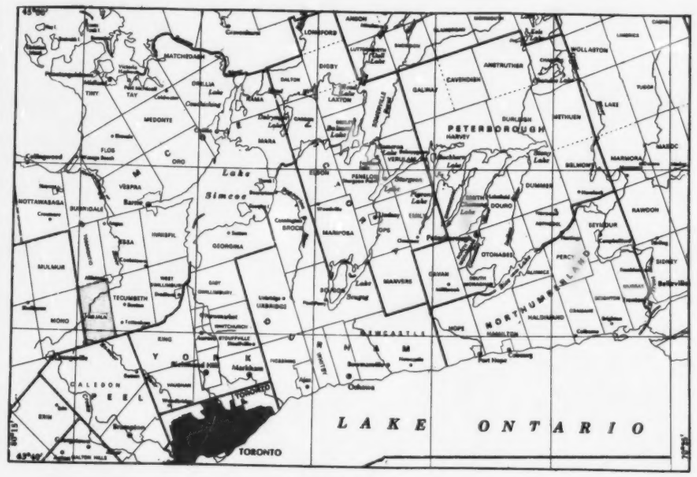

LEGEND

PALEOZOIC

ORDOVICIAN

UPPER ORDOVICIAN

QUEENSTON FORMATION
Red shale

GEORGIAN BAY FORMATION
Grey shale with limestone interbeds; limestone upper member on Manitoulin Island

WHITBY FORMATION
Grey and black shale

SYMBOLS

- Geological boundary.
- 25 — Drift thickness contour line (25 foot (8 m) interval).
- x — Isolated bedrock outcrop.
- Bedrock within 3 feet (1 m) of surface: see Table 4.
- Bedrock covered by 3 to 25 feet (1 m to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 m to 15 m) of overburden: see Table 4.
- Selected bedrock resource area; Deposit number: see Table 6.
- O 27 — Selected drilling location indicating reported depth to bedrock (in feet).

UPPER ORDOVICIAN

QUEENSTON FORMATI
Red shale

GEORGIAN BAY FORM
Grey shale with lime
stone upper member

WHITBY FORMATION
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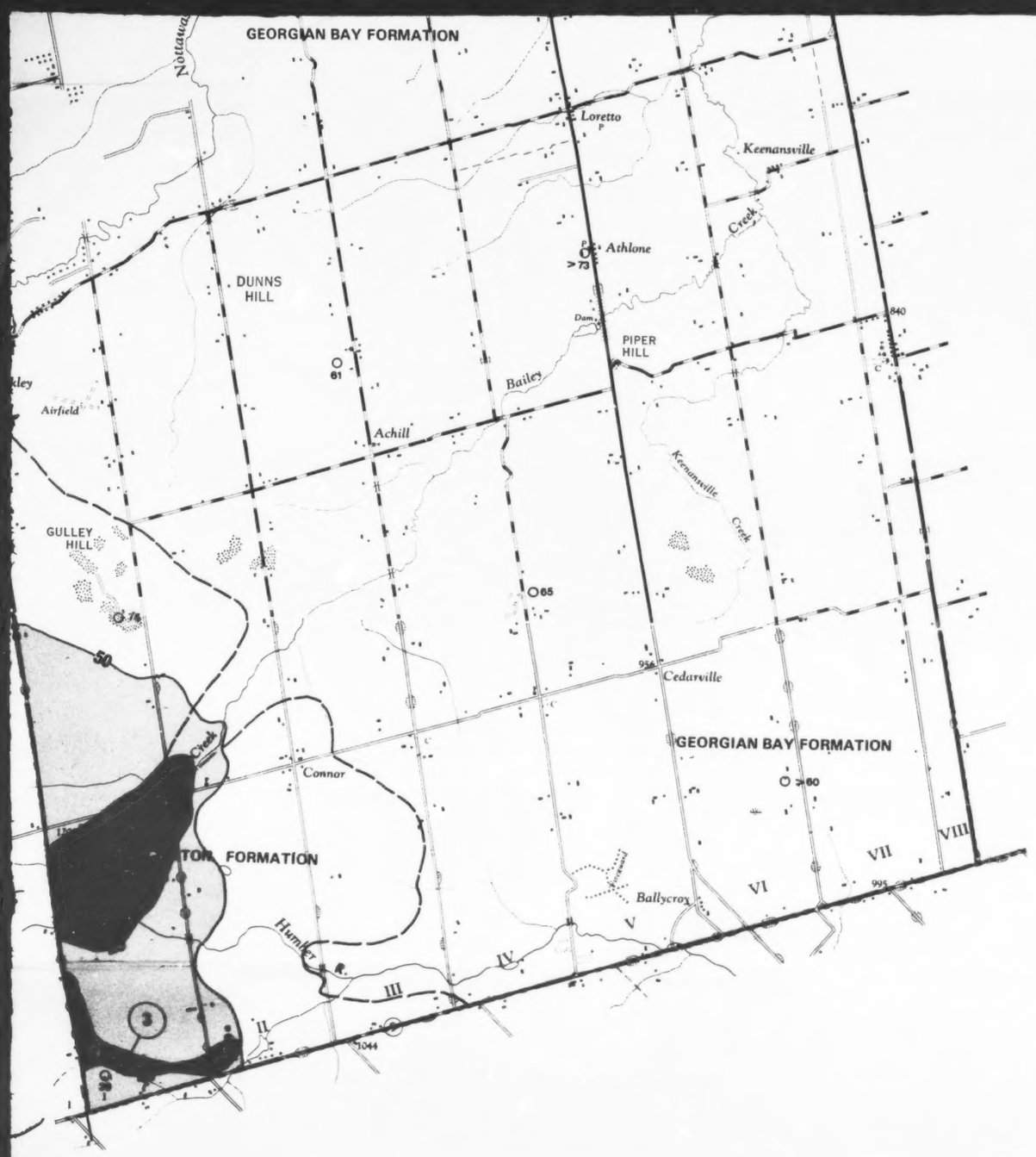

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